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Canada Centre for Mineral and Energy Technology
Centre canadien de la technologie des minéraux et de l'énergie

COMPILATION OF ABSTRACTS OF PAPERS FROM RECENT INTERNATIONAL CONFERENCES AND SYMPOSIA ON FLY ASH IN CONCRETE

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COMPILATION OF ABSTRACTS OF PAPERS FROM RECENT INTERNATIONAL CONFERENCES AND SYMPOSIA ON FLY ASH IN CONCRETE

by

E.E. Berry* and V.M. Malhotra**

SUMMARY

This report is a compilation of abstracts of papers from recent international conferences and symposia on the use of fly ash in concrete. The conferences covered include those held in Europe and North America between 1980 and 1983. Papers for the abstraction purposes were selected on the basis of their direct relevance to the use of fly ash in concrete. The abstracts are given in chronological order and keywords are included for each abstract.

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INTRODUCTION

In the past five years a number of conferences and symposia have been conducted on the use of fly ash and other mineral byproducts in portland cement concrete. The most notable have been the following:

- Seventh International Congress on the Chemistry of Cement; Paris, 1980.
- Fifth International Symposium on Concrete Technology, Nuevo Leon, Mexico, March 1981.
- Symposium on Fly Ash Incorporation in Hydrated Cement Systems, Materials Research Society, Boston, November 1981.
- EPRI Workshop on Research and Development Needs for Use of Fly Ash in Cement and Concrete, Palo Alto, Calif. March 3-5, 1982. Proceedings EPRI Report, CS-2616-SR (Sept. 1982).
- Sixth International Symposium on Fly Ash Utilization, Reno, Nevada, March 1982.
- International Symposium on the Use of PFA in Concrete, University of Leeds, England 14-16 April 1982.
- First CANMET/ACI International Conference on The Use of Fly Ash, Silica Fume Slag and Other Mineral By-products in Concrete, Montebello, Canada, July 31- August 5, 1983. Published as ACI Special Publication SP-79.

Abstracts of selected papers from these sources have been compiled in the present document as a supplement to a recent review of the use of fly ash in concrete prepared by the authors.

Papers were selected on the basis of their direct relevance to the practical application of fly ash to concrete construction. The reader is urged to consult the original proceedings of these meetings for further detailed consideration of the subject and to review the many excellent papers on research and other aspects of the subject not directly applicable to concrete construction.

This compilation is part of a CANMET project on the use of waste materials as supplements to portland cement and was made possible under a CANMET Contract (DSS Number 26 SQ.23440-3-9220) awarded to E.E. Berry and Associates.

ABSTRACTS OF PAPERS

The Seventh International Congress on the Chemistry of Cement; Paris, 1980.

Author: Owens, P.L. and Buttler, F.G.

Title: The Reactions of Fly Ash and Portland Cement with Relation to the Strength of Concrete as a Function of Time and Temperature.

Pages: Vol.3; IV.60 - IV.65

Abstract:

Where portland cement concrete is subjected to rises in temperature, due to the effect of the heat of hydration of the cement, the long term strength and durability of that concrete is usually adversely affected. Further when portland cement concrete is subjected at early ages, to excessively large temperature rises i.e. exceeding 60°C, the result is a concrete of restricted and limited strength reached within days, in contrast to that which is expected from the long term storage of concrete in water at 20°C.

By simulating different typical curing regimens to which concrete can be subjected the strength of the hydrate at different ages, with various combinations of portland cement and controlled quality fly ash, can be related to the quantity of lime, as $Ca(OH)_2$, found in the structure of the hydrate. It was also found that as the proportion of fly ash increased not only was there an improvement in strength, which increased with temperature of curing, but that in the hydrate there was an incidental reduction in the quantity of lime.

Within the range from nil to 75% fly ash as a proportion of the cement content, at about 30% fly ash, a maximum strength was attained at 28 days from curing at 80°C, this coincided with a reduction of about 50% in lime content of the hydrate. However, this amount of lime is more than sufficient to provide adequate protection to embedded steel reinforcement.

KEYWORDS:

curing, durability, fly ash, heat of hydration, lime, portland cement, strength, temperature.

ABSTRACTS OF PAPERS

The Fifth International Symposium on Concrete Technology, Nuevo Leon, Mexico, March 1981. Available from Dept. of Civil Engineering, University of Nuevo Leon, Monterrey, Mexico.

Author: Mehta, P.K.

Title: Sulphate Resistance of Blended Portland Cements Containing Pozzolans and Granulated Blast Furnace Slag.

Pages: 35-50

Abstract:

On account of energy considerations, the production and use of blended cements is expected to rise. Due to wide variations in the characteristics of blending materials, lack of reliable laboratory tests, and inadequate understanding of the factors responsible for durability to chemical attack, it is difficult to evaluate and predict performance, especially the chemical resistance of blended cements. With the object of clarifying the factors governing the behaviour of cements exposed to sulphate attack, a laboratory investigation was undertaken for determining the relationship between sulphate resistance and microstructure of hydrated cements. For this purpose, blended portland cements were made with several pozzolanic materials, namely a natural pozzolan, a fly ash, a rice husk ash, and a granulated blast-furnace slag. From the results it was concluded that the differences in pore size distribution of hydrated cement, rather than chemical composition, played a dominant role in determining the sulphate resisting behaviour of blended portland cements.

KEYWORDS:

blast furnace slag, blended cements, blended portland cements, chemical resistance, durability, fly ash, microstructure, pozzolans, rice husk ash, sulphate resistance.

Author: Philleo, R.E.

Title: Natural Pozzolan and Fly Ash in Mass Concrete.

Pages: 145-157

Abstract:

The Corps of Engineers has used pozzolan in virtually all of the mass concrete placed in dams and navigation locks during the past twenty years. Specifications have permitted the use of either natural pozzolan or fly ash. The choice has been dictated by the economics at each project. In most geographical locations fly

ash is the economical choice, but in the northwestern part of the country natural pozzolan has been used in eight major structures.

Pozzolan is used as a replacement for a portion of the cement on an absolute volume basis. Extensive research, which preceded the decision to use pozzolans, established maximum replacement quantities for exposed and unexposed concrete.

Concrete is proportioned to achieve the design strength in ninety days. In addition, it must be capable of developing a strength of 2.75 MPa in three days. The latter requirement is designed to protect against form anchor failures.

Properties of the hardened concrete have been excellent with strengths exceeding those of normal portland-cement concretes at later ages.

KEYWORDS:

economics, mass concrete, natural pozzolan, pozzolan, proportioning.

Author: Mather, B.

Title: Blends of Cementitious Materials for Concrete to be Exposed to Sea Water.

Pages: 289-310

Abstract:

With the increasing cost of energy and hence of energy-intensive products such as portland-cement clinker, increased attention is properly being given to the use of blends of portland cement with other materials for purely economic considerations. In sea-water exposures, concrete needs to be resistant top wetting and drying and to moderate sulphate attack. It usually must also be of low permeability to protect reinforcement from corrosion. Available laboratory data and field experience both indicate that blends of portland cement and pozzolan or portland cement and pulverized quenched iron blast-furnace slag have benefits for sea water exposure in addition to the reduced cost that should make them initially attractive. With these relations in mind, the factors relevant to the use of materials and the properties of concrete affected by exposure to sea water are reviewed.

KEYWORDS:

blast furnace slag, blended cements, pozzolan, reinforcement corrosion, sea water, sulphate attack, wetting and drying.

Author: Kanitakis, I.

Title: Permeability of Concrete Containing Pulverised Fuel Ash.

Pages: 311-322

Abstract:

The main aim of this work was to investigate whether English produced PFA (Pulverised Fuel Ash) concretes are impervious enough to be used for offshore structures., A representative OPC (Ordinary Portland Cement) concrete, of high cement content, and a corresponding PFA concrete were tested. These two mixes were designed to have basically the same workability amd cube strength, so that their permeability could be compared. The ISAT-test (as defined in BS 1881, Part 5, 1970-6. Test for Determining the Initial Absorption of Concrete) was adopted and measurements of the permeability were taken at 7,17,28 and 56 days. The results showed that the OPC mix has lower permeability than the PFA mix at early ages, but the difference tends to diminish at later ages. Detailed test results are reported in suitable form and discussed.

KEYWORDS:

absorption, offshore structures, permeability, portland cement, pulverized fuel ash, workability.

Author: Scanlon, J.M.

Title: Mixture Proportioning of Concrete Containing Natural Pozzolans, Fly Ashes, and Slags for Use in Seawater.

Pages: 323-349

Abstract:

Many concrete technologists are concerned for the resistance of concrete containing natural pozzolans, fly ashes, and slags to

deterioration by seawater. Concrete containing these materials can be made just as strong and durable as concrete containing straight portland cement. Procedures for proportioning concretes to assure adequate quality, durability, and placeability are discussed. The water-cement (W/C) ratio is emphasized and how to recompute effective W/C ratios by volume when using natural pozzolans, fly ashes, and slags is reviewed. Densities of the materials involved contribute to mixture proportioning problems, but due to the energy used in producing portland cement, we need to develop technology in using some of the otherwise less energy consumptive waste materials.

KEYWORDS:

durability, fly ash, mix proportioning, natural pozzolans, placeability, seawater, slags, waste materials, water-cement (W/C) ratio.

Author: Munn, R.L. and Ryan, W.G.

Title: Concretes in Australia Containing Fly Ashes and/or Slags: Their Properties and Performance in Aggressive Environments.

Pages: 369-392

Abstract:

Very significant use of both bituminous fly ashes and blast furnace slags has been made in Australian concretes since the first recorded use of air cooled blast furnace slag in 1923. During the last 16 years concretes containing fly ashes and ground granulated slags as partial cementitious components have been used in up to 80% of the concrete produced in major areas of Eastern Australia. Some concretes have utilized a tertiary blend of fly ash, ground granulated slag and portland cement, with considerable success. The locations of the plants producing slags and fly ash are such that a unique opportunity exists to study the long-term performance of concretes containing these materials in the marine environment.

Data have been collected from laboratory investigations into compressive strength development, shrinkage and creep and freeze-thaw resistance of a wide range of concretes utilizing slags and fly ash. Core samples have been taken from concrete in long-term service, tested for compressive strength and examined by scanning electron microscopy. Field surveys have been made on the durability of concretes under aggressive service conditions, including examination of wear and cracking patterns. In many cases, comparison between the performance of concretes containing slags and fly ashes is made with properties of traditional

concretes subjected to similar conditions.

Australian studies into durability of concrete structures have indicated that effects of salt spray on buildings has been greatly underestimated. Provided concretes are given adequate curing and compaction, pozzolanic binders play an important role in improving durability of concrete for buildings and marine structures.

It is concluded that with appropriate mix design, concretes containing slags and fly ashes can match the properties of conventional concretes in all respects.

KEYWORDS:

blast furnace slag, compressive strength, concretes, cracking, creep, durability, field surveys, fly ash, freeze-thaw resistance, marine environment, salt spray, shrinkage, slags, tertiary blend, wear.

ABSTRACTS OF PAPERS

The Symposium on Fly Ash Incorporation in Hydrated Cement Systems, Materials Research Society, Boston, 1981.

Author: Ravina, D.

Title: Production and Collection of Fly Ash for Use in Concrete.

Pages: 2-11

Abstract:

The setup of an electrical power station and the processes and operations involved are described from the viewpoint of their effect on the properties of the fly ash. The systems for collection, handling, beneficiation and storage are analyzed and their effect on the fly ash are evaluated. It is shown that suitable design of the collection and delivery system for new installations (or, in some cases, modification of the existing one) will lead to significant improvement in the quality of the fly ash as a concrete ingredient.

KEYWORDS:

beneficiation, collection, fly ash, handling, storage.

Author: Wesche, K. and vom Berg, W.

Title: Properties of Fly Ash Used in Germany.

Pages: 45-53

Abstract:

According to the German standard for concrete constructions (DIN 1045) fly ashes having an Agrement or approval can be used as a concrete admixture. This Agrement is granted to the fly ash of a single boiler if it fulfills a set of requirements. The properties of all fly ashes used in concrete must be continuously inspected.

On the basis of the large number of test results performed in connection with this continuous monitoring, a survey is given of the properties of coal fly ashes form 14 power plant boilers. This survey contains information about chemical composition and physical and mineralogical properties of fly ashes and some relevant properties of cement pastes and mortars containing fly ash.

In addition correlations between different fly ash properties are shown and discussed with regard to concrete technology and to the current control of fly ash.

KEYWORDS:

fly ash, Germany, standards, properties.

Author: Dodson, V.H.

Title: The Effect of Fly Ash on the Setting Time of Concrete - Chemical or Physical.

Pages: 166-171

Abstract:

All conditions being equal, i.e., the same cement, sand, coarse aggregate, water and temperature, the setting time of plain non-admixture concrete is a function of its cement factor (C.F.) and its w/c ratio. As the C.F. of a series of plain concretes is increased, the setting times of those concretes decrease. On the other hand, as the w/c ratio of a series of plain concretes is increased, the time of set of the concretes is extended. When the setting times of a given series of plain concretes are plotted as a function of their cement factors divided by their w/c ratios (C.F. - w/c), a straight line relationship is obtained. This straight line, or base line, can then be used to determine whether a given fly ash is altering the setting time of concrete by chemical processes or the result of what was done to the concrete to accommodate the fly ash, i.e., lowered C.F. and increased w/c ratio. If the setting time data point for the fly ash concrete falls on the base line its setting time is the result of the physical aspect. When the data point falls significantly below or above the base line, chemical interactions between the cement and fly ash or between the fly ash and water, in addition to the physical effects are influencing the setting time of the concrete.

KEYWORDS:

fly ash, mix proportions, setting time.

Author: Ravina, D.

Title: Fly Ash Concrete Under Hot Weather Conditions.

Pages: 172-183

Abstract:

Hot weather gives rise to problems in manufacturing, placing and curing portland cement concrete, in that it can adversely affect the properties and serviceability of the hardened material. Fly Ash (class F) from bituminous coal, by its nature, has a lower reaction rate compared to portland cement, thus developing its cementitious properties more slowly. This feature and its consequences, which are regarded as disadvantages in a moderate and particularly in a cold climate, may be beneficial in a hot one and alleviate some of the problems and difficulties in hot-weather concreting. The present work deals with the properties of fresh and hardened concretes, in which up to 30 percent of the ordinary portland cement was replaced by fly ash and which were mixed and cast at 20°C (68°F), and 40°C (104°F). It was found that slump decrease was smaller in the fly ash concretes; that the amount of mixing water to maintain a given slump at elevated temperature has to be increased also in fly ash concrete; and that the compressive strength of a constant water content fly ash concrete was not affected by the elevated temperature, while the strength of a constant consistency (slump) fly ash concrete was reduced.

KEYWORDS:

curing, fly ash, hot weather construction, workability.

Author: Dodson, V.H.

Title: The Strength Contribution of Fly Ash Concrete - A New Approach to its Estimation.

Pages: 184-193

Abstract:

When the same concrete materials (i.e. cement, sand, coarse aggregate) and curing conditions are employed in fabricating a series of non-admixture concretes, the compressive strengths of those concretes, at any age of test, are a straight line function

of their Omega Index Factors. The Omega Index Factor (O.I.F.) of a given concrete is calculated by dividing its cement factor by its water/cement ratio.

The position and slope of the x-y plot of compressive strength vs. O.I.F. varies with different cements. The straight line plots for the plain concretes can then be used to evaluate a given fly ash. For example, when concrete in which a portion of the cement is replaced with fly ash, is subjected to this type of analysis, the fly ash concrete data point will either fall on the straight line plots for the plain concretes, indicating no strength contribution, or above the straight line plots, indicating a definite strength contribution. The distance of the fly ash data point from the base line at the same O.I.F. can be used to estimate the magnitude of the strength contribution of the fly ash.

The strength contributions of several different fly ashes to concrete are reported and compared with the strength contribution of portland cement at the same ages of test.

KEYWORDS:

fly ash, mix proportioning, strength development.

Author: Ong, L.T.; Munday, J.G.L.; Dhir, R.K.

Title: Moisture Related Movements in OPC/PFA Concrete.

Pages: 204-213

Abstract:

The paper deals with movements in OPC/PFA concretes caused by continuous drying and alternate wetting and drying, comparison being sought with the corresponding OPC concretes. It is shown that drying shrinkage is related to the equivalent cement content of the concrete, but cannot be related to any other single fly ash characteristic. There is an optimum level of cement replacement by fly ash which improves the resistance of concrete to wetting/drying expansion.

KEYWORDS:

drying shrinkage, fly ash, moisture related movements, wetting and drying.

Author: Crow, R.D. and Dunstan, E.R. Jr.

Title: Properties of Fly Ash Concrete.

Pages: 214-224

Abstract:

The Bureau of Reclamation has been utilizing fly ash in concrete since the repair of Hoover Dam spillway in 1942; since that time our knowledge of its qualities, physical and chemical characteristics, and finished product properties has greatly expanded. Current performance evaluations of several concrete structures in which class F fly ash was used in quantities up to 30 percent of the cementitious materials lend insight on the properties of fly ash concrete. More recent fly ash projects include research into the characteristics of the class C ash. There are pronounced differences between the class C and F ashes, the most significant of which is Class C ashes are cementitious on their own. Properties discussed and compared include sulfate resistance, compressive strength, drying shrinkage, and freeze-thaw durability. Fly ash is a plentiful, low cost cementitious medium that is used with portland cement by the United States Bureau of Reclamation in most current concrete construction.

KEYWORDS:

Class C ash, Class F ash, compressive strength, drying shrinkage, fly ash, freeze-thaw durability, properties, sulfate resistance.

Author: Wesche, K. and Schubert, P.

Title: Properties of Mortars and Concrete Made With Fly Ash .

Pages: 225-232

Abstract:

Fly ashes from bituminous coal have been used for about ten years in the Federal Republic of Germany as an admixture to concrete in accordance with German standard DIN 1045. The principle results of such tests and of other research programs are the following:

The greater the fly ash content, the lower the strength at

early ages. The strength lag of the mortar or concrete with fly ash diminishes with increasing age. The modulus of elasticity of concretes with fly ash was higher than the modulus of concretes without fly ash. Shrinkage and resistance to freezing and thawing of mortars or concretes made with fly ash were not appreciably different from those without fly ash. A replacement of cement by fly ash to about 50 per cent increases the resistance to sulphate especially when cement with a lower sulphate resistance is used. For an equal reference compressive strength the carbonation behaviour of mortars and concretes containing fly ash is generally not appreciably different from the carbonation behaviour of concretes made without fly ash.

KEYWORDS:

carbonation, fly ash, freezing and thawing resistance, Germany, mortars, properties, shrinkage, strength at early ages, sulphate resistance.

Author: Ramakrishnan, V.; Coyle, W.V.; Brown, J.; Tlustus, P.A. and Venkataramanujam, P.

Title: Performance Characteristics of Concretes Containing Fly Ash.

Pages: 233-242

Abstract:

This paper presents the results of a performance evaluation study of concrete containing fly ash. The properties of fly ash concrete have been compared with their corresponding properties of regular concrete. The plastic properties of concrete compared are slump, air content, vebe-time, temperature, unit weight, and setting time of concrete. The hardened concrete properties compared are unit weight, compressive strength, split tensile strength, flexural strength, static modulus of elasticity, pulse velocity, and absorption coefficient. These properties are compared at four different ages: 3, 7, 28 and 90 days. Durability under rapid freeze-thaw conditions and shrinkage deformations are also discussed.

A comparison of the physical properties of fresh concrete on the basis of approximately equal slump and entrained air, has shown the relative ease of placing and finishing concretes containing fly ash. The rate of stiffening is lower for fly ash concretes containing Type I cement.

modulus at 90 days than their corresponding regular concretes. However, fly ash concrete has slightly higher drying shrinkage than regular concrete. The strength and elastic modulus relationships are approximately the same for both concretes.

KEYWORDS:

air entrainment, compressive strength, durability, elasticity, flexural strength, fly ash, freeze thaw, fresh concrete, hardened concrete, properties, pulse velocity, setting time, shrinkage, slump. split tensile strength, temperature, unit weight, workability.

Author: Cain, C.J.

Title: Effects of Various Types of Fly Ash on Behaviour and Properties on Concrete.

Pages: 260-268

Abstract:

The effects of four types of fly ash on the three major categories of concrete, mass, structural and paving and precast are discussed. Aspects of concrete production such as economy, workability, strength, and durability are examined in the light of the chemistry and physical characteristics of the four designated types of fly ash and their effects when added to concrete mixes. Class F fly ashes, those from anthracite and bituminous coals are reported on primarily for their low or high loss on ignition. Class C fly ashes, usually collected from the burning of sub-bituminous and lignite coals, are presented from the perspective of their Ca0 content and resulting cementitiousness or hydraulicity.

KEYWORDS:

Class C, Class F, chemistry, concrete production, durability, economy, fly ash, hydraulicity, loss on ignition, mass concrete, paving concrete, physical characteristics, precast concrete, properties, strength, structural concrete, workability.

Author: Manz, O.E.

Title: American and Foreign Characterization of Fly Ash for Use in Concrete.

Pages: 269-279

Abstract:

There are several federal and state specifications being used in the United States involving the use of fly ash in concrete. However, several foreign countries have separate specifications adopted for use by all agencies in the particular country. In the United States, the ASTM has been attempting to resolve the problem of reliable prediction of the contribution of fly ash when substituted for part of the cement in concrete. The widespread use of many different lignite and sub-bituminous coals has compounded the problem. The characterization of fly ash by reference to the type of coal has been criticized.

A review of the various specifications will be presented. The chemical and physical data for several fly ashes will also be presented. Some performance results involving the use of selected fly ashes in concrete will be given. A revised characterization scheme for fly ashes will be discussed.

KEYWORDS:

ASTM, characterization, concrete, fly ash, lignite, performance, specifications, sub-bituminous coals.

Author: Barker, W.R.

Title: The Distinction Between Water Reduction and Reactivity as the Factors Influencing Fly Ash Performance in Concrete.

Pages: 289-295

Abstract:

Attempts to evaluate the performance of South African fly ashes in blended cements showed poor correlation between the commonly used ash quality criteria of loss on ignition and fineness as related to performance in concrete. Accordingly, a concrete mix test program was devised in which the quality of fly ash could be quantified in terms of two parameters, water reduction, and a reactivity index or "cementing efficiency" of the fly ash. Test

data using this approach showed the marked difference in performance in concrete between two ashes which were thought to be basically similar. Two main conclusions are drawn from this study:

i) existing specifications for fly ash do not define its performance in concrete;

ii) the variation of influence of fly ash on the rheology of concrete is inadequately understood.

KEYWORDS:

blended cements, cementing efficiency, fineness, fly ash, loss on ignition, performance, reactivity, rheology, South African, specifications, water reduction.

Author: Raba, C.F. Jr.; Smith, R.L.; and Mearing, M.

Title: Sub-bituminous Fly Ash Utilization in Concrete.

Pages: 296-305

Abstract:

The use of bituminous fly ash as a mineral admixture for portland cement concrete has been well documented over the years. sub-bituminous fly ash, in comparison, has only recently begun to experience widespread utilization in the concrete products market. Therefore, only a limited amount of information on this Class C fly ash has been made available to architects, engineers, ready-mix concrete producers and contractors. This paper presents mix designs using various ash replacement values for combinations of different cements, aggregates and organic admixtures. The compressive strength of the concrete was found to vary considerably depending on the compatibility of the concrete constituents.

KEYWORDS:

admixtures, Class C fly ash, compressive strength, mineral admixtures, mix proportioning, portland cement, sub-bituminous fly ash.

Author: Martin, R. and Hilton, R.G.

Title: A Successful Application of the Use of Fly Ash in Specification Air-Entrained Concrete.

Pages: 306-314

Abstract:

Early in 1980, construction of a relatively large facility located to the north of Cincinnati, Ohio, was commenced. This project required production of approximately 60,000 cu. yds. of concrete over an eighteen month period. All the concrete incorporated Class F fly ash meeting the requirements of ASTM C618.

This paper discusses the performance of closely inspected concrete, air entrained and incorporating fly ash, which is batched at an off-site plant and mixed and delivered by truck mixer. Test data have been documented for nearly 18 months and variability of the following properties is analyzed: strength at 7 and 28 days, cylinder weight at 7 days, air content, slump, concrete temperature and time between sampling and leaving plant.

KEYWORDS:

air-entrained concrete, Class F, fly ash, slump, strength at concrete temperature.

ABSTRACTS OF PAPERS

The Electric Power Research Institute Workshop on Research and Development Needs for Use of Fly Ash in Cement and Concrete, Palo Alto, Calif. March 3-5, 1982. Electric Power Research Institute Report, CS-2616-SR, Sept. 1982.

Author: Sturrup , V.R.

Title: A Review of the Use of Ontario Hydro Fly Ash in Concrete.

Pages: 3.12 - 3.24

Abstract:

A review is presented summarizing the history of the use of fly ash by Ontario Hydro in concrete construction since 1950. Information on major structures incorporating fly ash is given. A discussion is presented of research activities conducted by Ontario Hydro. These include studies of carbon in fly ash, concrete mix proportioning, creep and durability.

KEYWORDS:

air entrainment, alkali-aggregate reactions, carbon, fly ash, mass concrete, mix proportioning, pozzolan, quality control.

Author: Norholm, A. and Osbaeck, B.

Title: Fly Ash Usage and Related R&D Activities in Denmark.

Pages: 3.25 - 3.36

Abstract:

A review is given of the production and use of fly ash in Denmark. Danish Standards are reported to permit the use of up to 5% fly ash in all portland cements. Fly ash is also used in the manufacture of cement clinker. Related R&D activities are discussed, including ash characterization, health hazards, quality control, mix proportioning and concrete properties.

KEYWORDS:

characterization, fly ash, health hazards, mix proportioning, pozzolan, quality control.

Author: Owens, P.L.

Title: Status of Fly Ash in UK Cement and Concrete.

Pages: 3.37 - 3.47

Abstract:

The accumulation of research and experience and the progress of British Standards and Codes of Practice has led to a wider engineering appreciation of the benefits that fly ash of controlled quality can give to structural concrete. It is clear that to define fly ash as a pozzolana leads to confusion and that it is better to define it as "fly ash" as is done with blast furnace slag. It is with this in mind that RILEM has just established a new technical committee, 67-FAB "Use of Fly Ash in Building".

KEYWORDS:

blast furnace slag, British Standards, concrete, fly ash, pozzolan, structural concrete

Author: Kruger, J.E.; Rossouw, A.F.G.; and van Dijk, J.

Title: The Use of PFA in Cement and Concrete: Research and Utilization in the Republic of South Africa.

Pages: 3.48 - 3.58

Abstract:

A review of South African work is presented and the following points are discussed.

(a) The production of PFA in South Africa is approaching 10 million tons per annum and is expected to double by the end of the century.

(b) South African PFA has similar properties to those reported for overseas PFA of similar composition.

(c) Its pozzolanic activity index correlates better with the percentage residue on a 45 micron sieve than with the specific surface.

(d) In the presence of lime under moist conditions and at ambient temperatures, it develops strength only very slowly.

(e) Cement-PFA blends produced by intergrinding develop better strength than blends produced by mixing.

(f) Replacement of a part of the portland cement with fine PFA gives mortars increased resistance to attack by sulphates and by soft water, and it affords a significant reduction in the expansion caused by the alkali-aggregate reaction.

(g) The use of PFA, especially in lean concrete, can lead to more economical mixes.

KEYWORDS:

alkali-aggregate reaction, blended cement, concrete, intergrinding, lime, mortars, PFA, pozzolanic activity, Republic of South Africa, research, sulphate resistance.

Author: Snel, A.

Title: Fly Ash Production and Utilization in the Netherlands.

Pages: 3.67 - 3.79

Abstract:

A general overview is presented of ash production and utilization in the Netherlands. Ash is used in the manufacture of cement clinker and in blended cements. Some aspects of the effects of fly ash on concrete properties are discussed.

KEYWORDS:

blended cement, Holland, intergrinding, pozzolan, research.

ABSTRACTS OF PAPERS

The Sixth International Symposium on Fly Ash Utilization, Reno, Nevada, March 1982. Available from National Ash Association, Washington, D.C.

Author: Smith, R.L.; Raba, C.F. Jr.; Mearing, M.A.

Title: The Utilization of Class C Fly Ash in Concrete.

Pages: Volume 1; 164-189

Abstract:

The utilization of Class F fly ash as a mineral admixture in portland cement concrete has been well established. Class C fly ash, in comparison, has only recently experienced widespread use as a concrete admixture. Although its utilization in concrete products has experienced considerable success in the field, only a limited amount of information on Class C fly ash has been made available to engineers, ready mix producers and contractors. This paper discusses in detail the utilization of one Class C fly ash in concrete. The Class C fly ash is produced at the J.T. Deely plant near San Antonio. The power plants use Wyoming sub-bituminous coal as fuel and the resulting fly ash possesses sufficient calcium oxide to harden in the presence of water. Data are presented on the effect of the fly ash content and mixing temperatures on the engineering properties of plastic and hardened concrete.

KEYWORDS:

admixture, Class C fly ash, concrete, engineering properties, mineral admixture, mixing temperatures, plastic and hardened concrete.

Author: Manz, O.E.

Title: Review Of American And Foreign Specifications For Use Of Fly Ash In Portland Cement Concrete.

Pages: Volume 1; 235-245. (See also Abstract on page 18.)

Abstract:

There are several federal and state specifications being used in the United States involving the use of fly ash in portland cement concrete. However, several foreign countries have separate specifications adopted for use by all agencies in the particular country.

In the United States, the classification of fly ash by reference to the type of coal has been questioned, as well as

some of the specification limits. The many new "Western" fly ashes have caused concern for some properties not presently covered, such as free lime and sulfate resistance.

A review of the various specifications will be presented, and will include a discussion of the similarities as well as items that are unique to a particular specification. An attempt will be made to present a universal specifications scheme for fly ashes.

KEYWORDS:

classification, fly ash, specifications.

Author: Ashby, J.B.

Title: Answers to the Objections to the Use of Fly Ash in Concrete.

Pages: Volume 1; 246-258

Abstract:

There have been any number of reasons given by specifiers for not allowing the use of fly ash in concrete covered by their specifications, by concrete producers for not using fly ash in thier product and by other groups and individuals not allowing the use of fly ash in concrete over which they have the say on what ingredients are used.

Some of the reasons advanced are based on technical grounds, some on ignorance, some on the economics and some on what is basically traditional belief amounting almost to folk-lore.

Often it is not a real reason at all, but the result of lethargy or just resistance to change. This paper critically reviews those reasons (or excuses) that are most frequently used and presents a realistic look at the facts.

KEYWORDS:

fly ash, economics, specifications.

Author: Pierce, J.S.

Title: Use of Fly Ash in Combating Sulphate Attack in Concrete.

Pages: Volume 2; 208-231

Abstract:

The paper describes sulphate attack in concrete and outlines its geographical concern to the Bureau of Reclamation. Examples of its destructive nature are shown. USBR testing procedures used to evaluate sulfate resistance are described. Current specification requirements for sulphate environments are listed, and how fly ash qualifies for these environments is discussed. A proposal for the ultimate in sulphate resistance specifications is also briefly discussed.

KEYWORDS:

concrete, fly ash, specifications, sulphate attack.

Author: Halstead, W. J.

Title: Quality Control of Highway Concrete Containing Fly Ash.

Pages: Volume 2; 394-407

Abstract:

This paper discusses the probable causes of the limited use of fly ash in highway concretes from the standpoint of potential problems with quality control. The counteracting effects of the additional testing and control problems on the economic incentives for using fly ash to replace a portion of the portland cement are discussed, It is recommended that the use of fly ash meeting ASTM Specification C618 be permitted at the option of a contractor with approval of the mix design by the state.

KEYWORDS:

highway concrete, quality control, testing.

ABSTRACTS OF PAPERS

The International Symposium on the Use of PFA in Concrete, University of Leeds, England 14-16 April 1982. Available from Dept. of Civil Engineering, University of Leeds, England.

Author: Owens, P.L. and Waddicor, M.J.

Title: Techniques for the Assessment and Production Control of Pulverized Fuel Ash for Use in Concrete.

Pages: 51-59

Abstract:

The authors have presented an overview of the techniques for quality control of fly ash for use in concrete in relation to the requirements of British standards. They suggest that, for a bituminous coal fly ash, the quality control parameters can be reduced to the monitoring of colour, loss on ignition and fineness. In addition, moisture content, SO_3 and density do affect the user of ash and require consideration. Methods of testing, frequency of testing and significance of tests are discussed.

KEYWORDS:

British standards, colour, density, fineness, fly ash, loss on ignition, moisture content, quality control, testing.

Author: Ellis, C.

Title: The Application of the Two-point Workability Test and the British Standard Tests to OPC/PFA Concretes.

Pages: 121-131

Abstract:

The use of a two-point test based upon measurements of rheological parameters in fresh concrete is discussed. Comparisons are made with conventional slump, V-B and compacting factor tests for workability. The author concludes that fly ash enhances the workability of fresh concrete.

KEYWORDS:

British standard, compaction, rheology, slump, workability.

Author: Ivanov, Ya. and Zacharieva, S.

Title: Influence of Fly Ash on the Rheology of Fresh Concrete,

Pages: 133-139

Abstract:

The authors relate the rheological properties of fly ash concrete to a Bingham model. Data obtained by using vibro-viscometers are presented to show the effects of fly ash on workability. Fineness of the ash and the mix proportions used are reported to be the main determinants of the rheological characteristics of fresh fly ash concrete. Improved workability is said to result from the use of ash with high specific surface area.

KEYWORDS:

fly ash, fresh concrete, mix proportions, rheology, specific surface, workability.

Author: Brown, J.H.

Title: The Strength and Workability of Concrete with PFA Substitution.

Pages: 151-159

Abstract:

The author reports an increase in workability when fly ash is substituted for cement such that for each 10% by weight of ash in the mix, an increase in workability is obtained equivalent to that attained by adding 3 to 4% of water. When ash is substituted for sand, workability was found to increase to an optimum level when the ash was present at about 8% by volume of aggregate. Above this level workabilty decreased.

KEYWORDS:

fly ash, strength, mix proportioning, workability.

Author: Banfill, P.F.G.

Title: An Experimental Study of the Effect of PFA on the Rheology of Fresh Concrete and Cement Paste.

Pages: 161-171

Abstract:

The author presents a general discussion of the application of a Bingham model to the rheology of fresh concrete and cement paste. He also discusses in some detail the equipment used to measure the rheological parameters of fresh concrete and the results of some experiments using fly ash concrete mixes. In general it is concluded that fly ash causes a reduction in yield stress but has little effect on the plastic viscosity of fresh concrete.

KEYWORDS:

cement paste, fresh concrete, viscosity, rheology, workability, yield stress.

Author: Ong, L.T., Munday, J.G.L. and Dhir. R.K.

Title: Mix Design for OPC/PFA Concrete.

Pages: 173-180

Abstract:

The proportioning of fly ash concrete to attain 28 day strength equivalent to comparable plain concrete mixes is discussed. Strength/proportioning relationships are presented for typical concrete mixes.

KEYWORDS:

fly ash, mix proportioning, strength.

Author: Brooks, J.J., Wainwright, P.J. and Cripwell, J.B.

Title: Time-dependent Properties of Concrete Containing Pulverized Fuel Ash and a Superplasticizer.

Pages: 209-220

Abstract:

The authors present data on strength, elasticity, creep and shrinkage for a range of concrete mixes incorporating both fly ash and superplasticizer. No significant adverse effects were observed from the use of fly ash. Creep of fly ash concrete was less than for plain concrete.

KEYWORDS:

creep, fly ash, elasticity, shrinkage, superplasticizer, time-dependent properties.

Author: Gifford, P.M. and Ward, M.A.

Title: Results of Laboratory Tests on Lean Mass Concrete Utilizing PFA to a High Level of Cement Replacement.

Pages: 221-230

Abstract:

The use of high levels of fly ash is reported to decrease the rapid load strain capacity and modulus of rupture in lean concretes. Thermal expansion, creep and autogenous volume change are reduced and drying shrinkage is increased.

KEYWORDS:

creep, elastic properties, drying shrinkage, fly ash, laboratory tests, mass concrete, thermal expansion.

Author: Munday, J.G.L., Ong, L.T., Wong, L.B. and Dhir. R.K.

Title: Load-independent Movements in OPC/PFA Concrete.

Pages: 243-254

Abstract:

The authors report that volume changes in hardened concrete due to changes in moisture content and temperature are reduced when fly ash is used as a partial replacement for cement. No effects of practical significance were found to result from the use of fly ash with respect to drying shrinkage, wetting/drying expansion, or coefficient of thermal expansion.

KEYWORDS:

drying shrinkage, fly ash, load-independent movements, temperature, thermal expansion.

Author: Yuan, R.L. and Cook, J.E.

Title: Time-dependent Deformation of High-strength Fly Ash Concrete.

Pages: 255-260

Abstract:

The use of a Class C fly ash as a partial replacement for cement in concrete is reported. It was concluded as follows:

- Normal, 60 MPa (28 days) concrete made with Type I portland cement and 20, 30 & 50% of a Class C fly ash developed equivalent strength and modulus of elasticity to a reference concrete, at 28 days.
- Such concrete with 20% ash had lower shrinkage and creep than reference concrete.
- With 30 or 50% ash, slightly higher shrinkage and creep were noted.

KEYWORDS:

class C fly ash, creep, high-strength concrete,

elasticity, shrinkage, time-dependent deformation.

Author: Dunstan, M.R.H.

Title: The Use of High Fly Ash Content Concrete in Roads.

Pages: 277-288

Abstract:

The use of high fly ash content roller compacted concrete in road construction in Britain is discussed with presentation of some case histories.

KEYWORDS:

fly ash, roller compacted concrete, road construction, roads, structural concrete.

Author: Blackie, A.D.

Title: The Influence of PFA on the Properties of Structural Concrete.

Pages: 289-299

Abstract:

The author presents a general overview of the properties of fly ash in structural concrete based on the experience of its use in Britain. Durability, structural parameters and quality control are discussed and some consideration is given to sulphate resistance and alkali-aggregate reactivity.

KEYWORDS:

alkali-aggregate, fly ash, durability, quality control, structural concrete.

Author: Williams, J.T. and Owens, P.L.

Title: The Implications of a Selected Grade of United Kingdom Pulverised Fuel Ash on Engineering Design and Use in Structural Concrete.

Pages: 301-311

Abstract:

The authors present a general review of the practical aspects of the use of fly ash in structural concrete. Selection and quality control of fly ash are considered and the properties and durability of fresh and hardened fly ash concrete are discussed.

KEYWORDS:

durability, fly ash, quality control, review, structural concrete.

Author: Woolley, G.R.

Title: Construction of Structures at Drax Power Station Using PFA Concrete.

Pages: 313-321

Abstract:

A case study of the use of fly ash concrete is presented. Specifications, economics and construction practices with fly ash concrete mixes are discussed.

KEYWORDS:

case study, economics, fly ash, structural concrete.

Author: Copeland, B.G.T.

Title: Concrete for Hydraulic Tunnels and Shafts, Dinorwic Pumped Storage Scheme - Case History.

Pages: 323-342

Abstract:

A case study of the use of fly ash concrete in tunnel structures is presented. Specifications, materials, quality control, and construction practices with fly ash concrete mixes are discussed.

KEYWORDS:

case history, fly ash, hydraulic tunnels, quality control, shafts.

Author: Swamy, R.N.

Title: Structural Properties of Fly Ash Concrete.

Pages: 343-355

Abstract:

Some of the engineering properties of fly ash concrete are discussed, including mix design and the results of tests conducted on concrete beams and slab-column connections. It was concluded that fly ash concrete can be satisfactorily designed to develop 1 day strengths equivalent to that of plain concrete. It is shown that structural members made from fly ash concrete exhibit satisfactory behaviour comparable with plain concrete.

KEYWORDS:

concrete beams, engineering properties, fly ash, mix proportioning.

ABSTRACTS OF PAPERS

The First International Conference on The Use of Fly Ash, Silica Fume, Slag and Other Mineral By-products in Concrete, Montebello, Canada, July 31- August 5, 1983. Editor V.M. Malhotra, ACI Special Publication SP-79.

Author: Mehta, P.K.

Title: Pozzolanic and Cementitious Byproducts as Mineral Admixtures for Concrete - A Critical Review.

Pages: 1-46.

Abstract:

Granulated blast furnace slag and low-calcium fly ashes have long been used as portland cement additives or as mineral admixtures in concrete. With the addition of high-calcium fly ash, rice husk ash, and condensed silica fume to the list of traditional admixtures, a scientific approach for characterization and evaluation of all industrial byproducts which are suitable for use as admixtures in concrete is needed. Since it is not the source of origin or the chemical composition of a mineral admixture but the mineralogical composition and particle characteristics which determine its contribution to concrete behaviour, in this review the entire area is treated as a unified discipline. This approach seems to provide a better basis for explaining the similarities and differences in behaviour between mineral admixtures originating from either the same or different sources. Mineralogical compositions, particle characteristics, current production rates, and utilization of major pozzolanic and industrial byproducts available in the United States and Canada are included. Mechanisms by which the use of these byproducts in portland cement concrete can improve engineering properties are discussed, and examples of data from field and laboratory investigations are given.

KEYWORDS:

alkali-aggregate, blast-furnace slag, concrete durability, fly ash, mineral admixtures, permeability, pozzolans, review, rice-husk ash, silica fume, sulphate resistance, thermal properties.

Author: Lamond, J.F.

Title: Twenty-five Years' Experience Using Fly Ash in Concrete.

Pages: 47-69.

Abstract:

The U.S. Army Corps of Engineers has used fly ash as a material

that partially replaces portland cement in concrete for twenty-five years. Initially research was performed on use of fly on concrete properties for bleeding, permeability, heat rise, resistance to freezing and thawing, elasticity, and compressive and flexural strength development. The concrete materials properties affected by partial replacement of portland cement with fly ash were heat rise in mass concrete, resistance to freezing and thawing and strength development. The concrete materials properties of three massive concrete gravity dams are reported. Since construction, these dams have been periodically inspected. Although these structures have some minor cracking, spalling, and erosion, their performance has been similar to other concrete gravity dams constructed using concrete without fly ash. Cost savings per cubic yard of concrete has been the benefit derived from using fly ash as a partial cement replacement material in massive concrete structures. Fly ash is specified to conform to ASTM C168, Class C or Class F with modifications to this specification as needed based on location or type of structure. Fly ash may replace portland cement up to 35 percent by absolute volume in interior mass concrete and 25 percent by absolute volume in exterior mass concrete and in structural concrete. Fly ash concrete has performed satisfactorily on Corps of Engineers projects over the last twenty-five years.

KEYWORDS:

bleeding, concrete durability, cost savings, cracking, erosion, flexural strength, fly ash, freeze-thaw, mass concrete, mix-proportioning, permeability, portland cement, spalling, specification, temperature rise, workability.

Author: Sturrup, V.R., Hooton, R.D. and Clendenning

Title: Durability of Fly Ash Concrete.

Pages: 71-86.

Abstract:

Since before the first utilization of imported fly ash by Ontario Hydro as a pozzolan in mass concrete in 1950, research programs on many aspects of its influence on durability were undertaken. Major areas addressed have been: 1. thermal crack resistance in mass concrete; 2. reduction of alkali reactivity; 3. freezing and thawing resistance, and 4. sulphate resistance (preliminary).

When the first fly ash was produced by Ontario Hydro from thermal plants used for peak load power, the problems with utilizing variable and often high carbon content fly ash were also studied. This problem was overcome by selective storage along with provision for fineness and carbon content checks for each tanker of ash leaving the plant.

Major findings of the research include:

Fly ash has and is being used successfully in lieu of both CSA Types 20 and 40 (ASTM Types II and IV) moderate and low-heat cements to control temperature rise and thermally induced cracking in mass concrete.

The replacement of 25 percent of normal portland cement with fly ash has been found to be effective in reducing alkali silicate expansions.

As long as adequate air contents are obtained, carbon content does not adversely affect the freezing and thawing resistance of concrete at least within the 12 percent CSA and ASTM limits. As long as carbon contents are established for each delivery of fly ash, dosages of air entraining agents can be modified easily.

KEYWORDS:

air entrainment, alkali reactivity, alkali silicate expansions, carbon, durability, fly ash, freeze-thaw, mass concrete, pozzolan, sulphate resistance, thermal cracking, temperature rise.

Author: Yamato, T. and Sugita, H.

Title: Shrinkage and Creep of Mass Concrete Containing Fly Ash.

Pages: 87-102.

Abstract:

Three types of cements and three types of fine aggregates, vis seashore sand, crushed stone and a blend of the two were utilized for this study. The water-to-cement ratio by weight ranged from 0.40 to 0.50. All mixes were made at a slump of 10-cm (4-in.) and air content of 4 percent.

The blended cement concrete with fly ash showed the lowest shrinkage among the three cement concretes. The creep tests showed similar results. Good workability, high strength, low shrinkage and creep could be achieved using fly ash concretes.

KEYWORDS:

creep, fly ash, mass concrete, portland cement, shrinkage, workability.

Author: Gebler, S. and Klieger, P.

Title: Effect of Fly Ash on the Air-Void Stability of Concrete.

Pages: 103-142.

Abstract:

Concretes containing both portland cement and fly ash were evaluated to determine the effect of fly ash on air-void stability. Ten fly ashes were used, they have a wide range of chemical and physical properties as well as geographical origins.

Air contents of plastic concretes were determined, and both air content and air-void parameters were measured in hardened concretes cast at four time intervals after initial mixing. These tests indicate that air contents of concretes containing Class C fly ash appear to be more stable than those in concretes containing Class F fly ash. The higher the organic matter content of a fly ash, the higher will be the air-entraining admixture requirement, the greater is the air loss on extended mixing. Even though the air volume is reduced, the spacing factor, specific surface, and number of voids are little affected.

A "Foam Index" was determined for each of the ten fly ash-portland cement combinations. Air-entraining admixture requirements of actual concretes containing both portland cement and fly ash were compared to the "Foam Index" test results. These tests indicate that the "Foam Index" could be especially useful to concrete producers as a quality control test for checking the air-entraining admixture requirements for different sources of lots of fly ash.

KEYWORDS:

air-entrainment, Class C, Class F, fly ash, foam index, portland cement, pozzolan, testing.

Author: Samarin, A., Munn, R.L. and Ashby, J.B.

Title: The Use of Fly Ash in Concrete - Australian Experience.

Pages: 143-172.

Abstract:

The paper describes commercial use of concretes containing fly ash in Australia. Comparison is made between fly ash and other concrete types, mainly on the basis of equal 28 day strength. Setting times, bleeding, workability, air entrainment, rate of strength gain, elastic properties, flexural and indirect tensile strength, heat of hydration, shrinkage creep, sulphate resistance, carbonation, abrasion resistance, alkali aggregate reactivity are discussed. Field observations of concrete structures containing fly ash after prolonged environmental exposure are also included.

KEYWORDS:

abrasion resistance, air entrainment, alkali-aggregate, Australia, bleeding, carbonation, concrete, elastic properties, field observations, flexural, fly ash, heat of hydration, reactivity, setting time, shrinkage, creep, strength gain, sulphate resistance, workability.

Author: Korac, V. and Ukraincik, V.

Title: Studies into the Use of Fly Ash in Concrete for Water Dam Structures.

Pages: 173-185.

Abstract:

The paper describes investigations undertaken to develop a suitable fly ash blended portland cement for concrete used in two large water dam projects in Yugoslavia, which have recently been completed. The fly ash selected for this purpose is produced at a power station using brown coal with combustion temperatures

1550 - 1600°C, as compared to other Yugoslavian power stations using lignite coal with combustion temperatures generally in the range of 1000 - 1200°C. It was shown that the combustion temperature is the single most important factor in controlling the quality of fly ash, with excellent physical and pozzolanic properties being produced at higher temperatures. A fly ash content (F) of 50% in portland cement (C),1 i.e. F/(F + C) = 0.50, was selected for these projects, as it was shown to be the most suitable blend with regard to the heat of hydration, setting time, consistency and soundness properties. A concrete mix with 225 kg/m^3 of this fly ash blended portland cement and aggregate of maximum size 63 mm (2 1/2 in.) was adopted and both the laboratory and site tests showed this mix to posses good properties in the fresh and hardened states. A comparison of these results was made with the comparable concrete prepared with commercially available portland cement and slag cement, and the use of fly ash blended portland cement was found to be advantageous.

KEYWORDS:

blended cement, fly ash, mass concrete, physical properties, portland cement, pozzolan, slag, Yugoslavia.

Author: Manz, O.E.

Title: Review of International Specifications for Use of Fly Ash in Portland Cement Concrete.

Pages: 187-200.

Abstract:

There are several federal and state specifications being used in the United States involving the use of fly ash in portland cement concrete. The American Society for Testing and Materials established a standard on fly ash in 1954 and several foreign specifications that followed had similar formats. However, the various foreign countries have separate specifications adopted for use by all agencies in that particular country. In recent years there have been a few other proposed unique classification systems.

In the United States, the classification of fly ash by reference to the type of coal has been questioned, as well as some of the specification limits. The many new "Western" fly

ashes have caused concern for some properties not presently covered, such as free lime and sulphate resistance. Also, due to poor correlation between laboratory pozzolanic activity tests and field performance, there is a need for a system in terms of parameters controlling performance.

A review of the various specifications will be presented, and will include a discussion of the similarities as well as items that are unique to a particular specification scheme for fly ashes.

KEYWORDS:

free lime, fly ash, international specifications, portland cement, pozzolanic activity, review, sulphate resistance.

Author: Rossouw, E. and Kruger, J.

Title: Review of Specifications for Additions for Use in Concrete.

Pages: 201-220.

Abstract:

Several countries have specifications for additions that are used in concrete, such as fly ash (pulverised fuel ash) or other pozzolans and vitreous blast-furnace slag, while other countries are preparing specifications for such materials. This paper lists the more important existing specifications and summarizes, compares and discusses their specific requirements. The differences and similarities of nomenclature, requirements and methods of test are indicated. Attention is given to the relationship between the results obtained from a test and the material's performance in use. Specification test results may not always be valid criteria for forecasting the performance of a material.

A proposal is made for a more uniform system of nomenclature, specification and testing for concrete additions:

KEYWORDS:

admixtures, blast-furnace slag, fly ash, nomenclature, performance, pozzolans, review, specifications, standards, testing.

Author: Mather, B.

Title: Cement User's Expectations with Regard to Blended Cements.

Pages: 255-265.

Abstract:

In current practice in the USA, the term "blended cements" is applied only if the addition to portland cement is blast-furnace slag or pozzolan. Blended cements are covered by ASTM specification C 595 and the most generally used types (IS and IP) are required to give a level of "performance" as good as Type I cement. The user, if he pays the same price per unit mass purchased, pays a lower price per solid volume.

A few people believe that a greater degree of sulphate resistance of concrete could be attained by the addition of a "suitable" pozzolan to Type V portland cement. Some pozzolans with high silica content can improve the sulfate resistance of an otherwise non-sulphate resistant portland cement, other pozzolans can make sulphate-resistance worse.

Merits or demerits in the performance of cements may be quite unrelated to whether or not the cement is "blended". As ASTM specifications require that IS and IP cements meet the same 3-day strength limits as Type I portland cements, such blended cements are seldom competitive in mass concrete construction.

Batching of pozzolan or slag at the ready-mixed concrete plant has the advantage that a wider range of admixture materials may be made available and the quantity of blending material can be varied at will. The disadvantages are that there is another ingredient to procure, test, store, and control and that it is possible to make a concrete with all slag or pozzolan and no portland cement. U.S.A. specifications for blended cements and for pozzolans still show serious deficiencies. For instance, the present classification of fly-ashes into Type F and C is misleading. Also, no basis exists for measuring for specification purposes the benefits of blended cement as compared with a straight portland cement with regard to sulphate resistance or reduction in tendency to concentrate expansion due to alkali-silica reaction.

The view is expressed that prices should be fixed according to performance requirements. If the customer wants more early strength or lower heat, the extra costs should be added on to the basic price.

Producers of hydraulic cements in general and of blended cement

in particular will have great opportunities in the future if they are aware that cement production is part of the chemical industry and concrete making is not simply putting mud in a hole. Quality control can save costs and permit the use of a variety of cements of a variety of levels of performance and prices. To make progress, efforts in research and development must be improved. Better methods of characterizing slags and pozzolans for better specifications must be developed.

KEYWORDS:

alkali-silica reaction, blast-furnace slag, blended cements, mass concrete, portland cement, pozzolan, quality control, sulphate resistance.

Author: Munday, J.G.L., Ong, L.T. and Dhir, R.K.

Title: Mix Proportioning of Concrete with PFA: A Critical Review.

Pages: 267-288.

Abstract:

Studies relating to proportioning of concrete incorporating pulverized-fuel ash (pfa) as a partial replacement of cement (OPC/PFA concrete) are reviewed. Three different approaches are identified: simple replacement, modified replacement and rational methods and their implications are discussed, particularly effects on the properties of resulting concrete, practical applications and the optimum utilization of fly ash. It is suggested that OPC/PFA concrete should be designed without reference to control OPC concrete and a mix design method is proposed for this purpose which is sufficiently simple for use in practice and is similar to current practice for OPC concrete design. It is hoped that this may lead to the development of a more widely acceptable mix design method for OPC/PFA concrete.

KEYWORDS:

admixtures, blended cements, fly ash, mix proportioning.

Author: Hobbs, D.W.

Title: Influence of Fly Ash upon the Workability and Early Strength of Concrete.

Pages: 289-306.

Abstract:

Workability and strength measurements made on concretes in which up to 20 percent by weight of the aggregate was replaced by an equal volume of fly ash are described. This method of proportioning the concrete mix has the advantage that both the water-portland cement ratio and the volume of the water-portland cement fraction can be held constant so that the extent to which fly ash is inert or cementitious at early ages can be assessed. It is shown that the variations in slump are in broad agreement with the predictions for a Bingham suspension in which a proportion of the particles is replaced by an equal volume of finer particles and that the strength contribution attributed to the fly ash is dependent upon the water-portland cement ratio.

KEYWORDS:

early strength, fly ash, mix proportioning, rheology, workability.

Author: Yuan, R.L. and Cook, J.E.

Title: Study of a Class C Fly Ash Concrete.

Pages: 307-319.

Abstract:

This paper describes an experimental investigation into the behaviour of fly-ash concrete with respect to strength, durability, shrinkage and creep deformations. A sub-bituminous coal ash conforming to Class C requirements of ASTM C-618 was used. The use of fly ash as a partial replacement for cement ranges from twenty percent to fifty percent by weight of the cement. These studies confirm that (1) the rate of strength development of Class C fly ash concrete is comparable with that of portland cement concrete; (2) the effect of fly ash content on the shrinkage deformation is not as significant as the effect of water/cement ratio, (3) for a given water/cement ratio, creep deformation is influenced by the fly ash content and (4) concrete

with a fly ash content of 20 percent replacement shows a better freeze-thaw durability than portland cement concrete.

KEYWORDS:

Class C fly ash, creep, fly ash, freeze-thaw durability, portland cement, shrinkage, strength.

Author: Ho, D.W.S. and Lewis, R.K.

Title: Carbonation of Concrete Incorporating Fly Ash or a Chemical Admixture.

Pages: 333-346.

Abstract:

Straight portland cement concrete and other concretes containing fly ash or a chemical water-reducing agent were investigated for the rate of carbonation.

Results have indicated that concrete having the same strength and water/cement ratio do no necessarily show the same rate of carbonation. For a strength level of 25 MPa, concrete containing fly ash carbonated 50% faster than the straight portland cement concrete.

KEYWORDS:

carbonation, chemical admixture, durability, fly ash, portland cement, water-reducing agent.

Author: Joshi, R.C. and Natt, G.S.

Title: Roller Compacted High Fly Ash Concrete (Geocrete).

Pages: 347-366.

Abstract:

Use of sub-bituminous, 'C' fly ashes from Alberta, a province in Western Canada, for producing high fly ash roller compactable concrete or geocrete was investigated. Optimum moisture content and maximum density of each of the mixes containing sand and gravel as coarse and fine aggregate respectively, and mixtures of

fly ash and cement, and fly ash and lime as cementitious materials were evaluated by geotechnical methods. Compaction and strength characteristics of the mixes containing various proportions of aggregate and cementitious material were evaluated in the laboratory. Durability characteristics and flexure strength of the selected mixes were also studied. The results indicate that the two sub-bituminous fly ashes, from Western Canada, can be used to produce high fly ash concrete suitable for pavements and core of gravity dams.

KEYWORDS:

blended cement, Class C fly ash, durability, flexural strength, geocrete, pavements, roller compaction.

Author: Buttler, F.G., Decter, M.H., and Smith, G.R.

Title: Studies on the Desiccation and Carbonation of Systems Containing Portland Cement and Fly Ash.

Pages: 367-381.

Abstract:

Cement/sand mortar cubes, some containing fly ash, have been subjected to a number of curing regimes involving desiccation and carbonation using a high partial pressure of carbon dioxide. The compressive strengths of the cubes were determined without fracturing them by applying an increasing axial load whilst the lateral strain on the cubes was monitored continuously. After the compressive strengths had been determined the cubes were sectioned and each section analysed for calcium hydroxide and carbonate content.

The results show that, following curing at 20°C only and particularly when the pozzolanic reaction of the fly ash was restricted by desiccation, the cubes containing fly ash carbonated more readily than comparable ones in which fly ash was absent. With higher water contents and with non-desiccated cubes those containing fly ash performed in a similar way to those that did not.

KEYWORDS:

carbonation, desiccation, fly ash, mortars, portland cement, pozzolanic reaction.

Author: Nasser, K.W. and Marzouk, H.M.

Title: Properties of Concrete Made with Sulphate Resisting Cement and Fly Ash.

Pages: 383-395.

Abstract:

This investigation is a study of the structural properties of concrete made with sulphate-resisting cement (Type V) and Saskatchewan fly ash. Tests were performed on cylinders exposed to temperatures of 70° to 450°F (21.4° to 232°) for periods of six months and over. The properties of strength, elasticity, creep and creep recovery were studied for both sealed and unsealed specimens.

Test results revealed that temperature had minor effect on strength and stress-strain relationship for both sealed and unsealed specimens; however, the modulus of elasticity showed a continual decrease with a rise in temperature.

Creep of unsealed concrete increased with an increase in temperature up to 160°F (70°C) and decreased thereafter, while creep of sealed specimens decreased with a rise in temperature, except at 350°F (177°C) where it was one and a half times that at 70°F (21.4°).

KEYWORDS:

creep, elasticity, fly ash, sulphate-resisting cement, temperature effects.

Author: Bordonado, G. and Nissoux, J.L.

Title: Road-Building Concretes Incorporating Fly-Ash or Slag.

Pages: 471-493.

Abstract:

The energy crisis calls for economy in all fields. Roadmaking, which consumes a great amount of materials of all kinds, is of all civil engineering sectors one in which the constructor can - all other things being equal - take the greatest technical risks. In this field, innovation is permanent, and the passage from the laboratory to the working site is a very rapid one.

For more than 20 years past, French roadmaking techniques have made use of industrial wastes, those whose properties make them veritable hydraulic binders: blast furnace slag and fly-ash. Some years ago, under the pressure of the need to economize materials and energy, there was a rediscovery of the value of rigid structures consuming a lesser quantity of materials, using binders involving a lesser consumption of energy, and above all not requiring a bituminous wearing course.

By extrapolating optional techniques, internally vibrated pavement concrete and compacted treated gravels, an attempt was made to establish a better recognition of the binding properties of slag and fly-ash in order to achieve highly economical techniques of rigid pavement construction.

Some motorways were recently built in which cement was replaced by around 30% by fly-ash or pulverized slag. This communication describes how the characteristics of these concretes were worked out, how they were obtained and applied throughout the implementation of the project, how systems of control were adapted, and what difficulties were encountered.

Simultaneously, a promising evolution of the technique of rigid pavements having recourse to the pozzolanic properties of fly-ash is emerging: compacted concrete. This communication indicates the principal properties of the material as revealed in the laboratory and on experimental sites, together with the difficulties encountered and the possibilities of development of this technique.

Taking advantage of the binding properties of industrial by-products does not present major technical difficulties provided that in each case allowance is made for contractural demands, means of control and in certain cases, methods of production and laying. The risks assumed by the contractor are

higher than if he uses a standardized industrial product, guaranteed by the producer; but in many cases, the economy achieved amply offsets the additional control required to cover those risks.

KEYWORDS:

blast furnace slag, fly ash, industrial wastes, pozzolanic properties, pavement, slag.

Author: Mailvaganam, N.P. ; Bhagrath, R.S. and Shaw, K.L.

Title: Effects of Admixtures on Portland Cement Concretes Incorporating Blast Furnace Slag and Fly Ash.

Pages: 519-537.

Abstract:

The effect of chloride, chloride free accelerators and superplasticizer admixtures on the physio-chemical properties of two types of concrete were determined. Fly ash and slag at 30% cement replacement by weight were compared to a reference mix with 100% normal portland cement. Two series of mixes utilizing different admixture dosages and cured at two temperatures (22°C and 5°C) were investigated. The compressive strength results and temperature time curves indicate that at 22°C all three admixtures were effective in offsetting the early strength reduction due to cement replacement. With the exception of fly ash mixes, 28 day strengths were close to and in some instances exceeded the strength of the 100% portland cement mixes. At lower temperatures (5°C) the performance of conventional accelerating admixtures was marginal in comparison with the superplasticizer. In general, the order of admixture effectiveness observed in both series of mixes was in the order: superplasticiser > chloride > non-chloride.

KEYWORDS:

accelerators, admixtures, blast furnace cement, fly ash, portland cement, setting, slag, strength, superplasticizer, temperature.

Author: Warris, B.

Title: Strength of Concrete Containing Secondary Cementing Materials.

Pages: 539-557.

Abstract:

The paper describes a model for the calculation of the strength of concrete with secondary materials. The model is based upon the type of correlation between strength and water-cement ratio (or water + air to cement ratio) originally suggested by Feret and later modified by Bolomey. An important additional parameter is introduced, viz:

E_r = efficiency function, describing the influence of the secondary material on the concrete strength.

The variation of E_r has been studied by means of experiments dealing with the binding of Ca0 or with the strength of concrete containing fly ash or silica fume.

KEYWORDS:

fly ash, secondary cementing materials, silica fume, strength, water-cement ratio.

Author: Swamy, R.N.; Ali, S.A.R.; and Theodorakopoulos

Title: Engineering Properties of Concrete Composite Materials Incorporating Fly Ash and Steel Fibres.

Pages: 559-588.

Abstract:

Three major factors, namely environment protection, energy savings, and inherent technical advantages, demand that fly ash of controlled quality and composition be incorporated in all concrete construction. This paper shows that concrete of sturctural quality containing fly ash, steel fibres, normal weight or lightweight aggregates and a plasticizing / water - reducing admixture or a superplasticizer can be designed to produce cohesive and workable mixes that enable easy transportation, pumping, compaction and finishing of the material. It is also shown that such mixes can be easily and

satisfactorily vibrated into place in structural members with bar reinforcement and thin sections. Mixes designed by partial but direct replacement of 30% by weight of cement can have early strength and elasticity properties comparable to concrete without fly ash, and exhibit structural behaviour similar to normal concrete. Extensive data are presented to demonstrate the applicability of these materials in practice.

KEYWORDS:

compaction, early strength, elasticity, finishing, fly ash, lightweight aggregates, plasticizing, pumping, steel fibres, superplasticizer, water-reducing admixture, workability.

Author: Carette, G.G. and Malhotra, V.M.

Title: Early-Age Strength Development of Concrete Incorporating Fly Ash and Silica Fume.

Pages: 765-784.

Abstract:

Early-age strength development of concrete in which part of the portland cement has been replaced by low-calcium fly ash tends to be slow, because fly ash acts as a relatively inert component during this period of hydration, though at later ages it contributes significantly to strength development. It was considered that the problem of low early-age strength of portland cement-fly ash concrete could be overcome by the incorporation of small amounts of condensed silica fume, a very fine and more rapidly reactive pozzolan.

This report presents the results of an investigation on the early-age strength development of concrete incorporating 30% low calcium fly ash, and to which small amounts of condensed silica fume have been added. The amounts of the fume ranged from 0 to 20% by combined weight of the portland cement plus fly ash. A total of thirty 0.06-m^3 concrete mixtures with water-(cement + fly ash) ratios ranging from 0.40 to 0.80 were made; 240 cylinders were tested in compression and 180 prisms were tested in flexure. A supplementary series of six concrete mixtures was made to determine the effect of silica fume and fly ash on the long-term strength development of concrete.

Test data showed that the incorporation of condensed silica fume increased the compressive strength of concrete at all ages

as compared with the compressive strength of the control concrete (70% portland cement + 30% fly ash). At 7 days, the loss of compressive strength due to the partial replacement of cement by fly ash was completely overcome by the addition of 10% condensed silica fume for concretes with water - (cement + fly ash) ratios ranging from 0.40 to 0.60; 15 to 20% was required for concretes with higher water - (cement + fly ash) ratio. At 28 days, regardless of the water - (cement + fly ash) ratio, the effect was generally achieved with less than 5% silica fume addition. The later age strength development of portland cement-fly ash concrete did not appear to be impaired by the use of condensed silica fume indicating availability of sufficient lime for the fly ash pozzolanic activity.

KEYWORDS:

age-strength relations, fly ash, plasticizer, portland cement, pozzolan, silica fume, strength.

Author: Virtanen, J.

Title: Freeze-Thaw Resistance of Concrete Containing Blast-Furnace Slag, Fly Ash or Condensed Silica Fume.

Pages: 923-942.

Abstract:

The use of ground blast-furnace slag and fly ash has increased considerably in Finland so far, but research on its properties has been carried out for some years. The use of these materials has been limited because of the lack of knowledge on the durability of concrete containing slag, fly ash or silica. The freeze-thaw resistance of concrete has been evaluated using five different methods. Both air-entrained and non-air-entrained concretes were tested.

KEYWORDS:

air-entrainment, blast-furnace slag, durability, fly ash, freeze-thaw resistance, silica fume.

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